Multiple Target Laser Designator (MTLD)

Quarterly Status Report #6

Contract No. N00014-05-C-0423

Period of Performance: 08/23/05 to 04/23/07

Reporting Period: 11/24/06 to 02/23/07

Technical Monitor:
Dr. Jonathan Curley
Office of Naval Research
Dahlgren, VA

Contractor:
Physical Optics Corporation
Electro-Optics & Holography Division
20600 Gramercy Place, Building 100
Torrance, CA 90501

Principal Investigator:
Russell Kurtz, Ph.D.
Phone: (310) 320-3088
Fax: (310) 320-4667

March 2007

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **21 MAR 2007**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Multiple Target Laser Designator (MTLD)**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Diffusion Pharmaceuticals, LLC 2020 Avon Court #4 Charlottesville, VA 22902**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**8**	

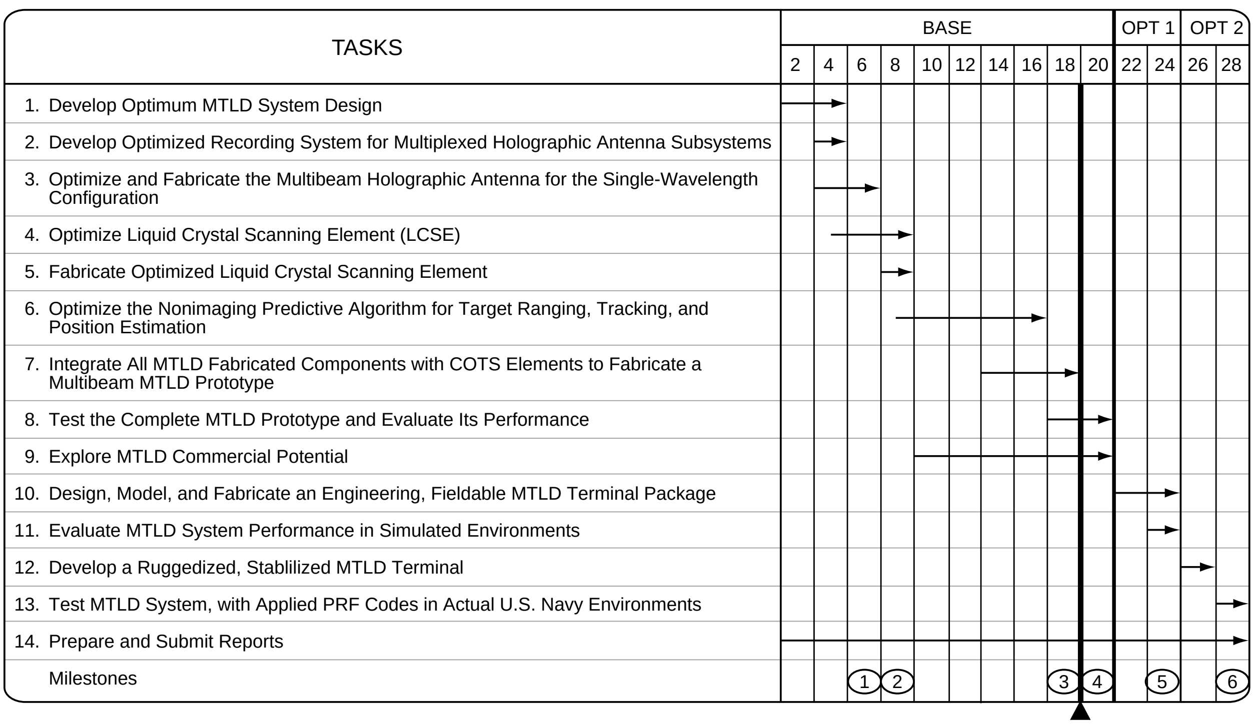
1.0 INTRODUCTION

Physical Optics Corporation (POC) is developing a Multiple Target Laser Designator (MTLD) based on a scanning element and a lightweight angular multiplexed holographic optical element (HOE) antenna. It has a wide field of view (FOV) with only a few detectors, and requires no additional hardware for beam pointing and tracking.

In the sixth quarter of the MTLD project, we have optimized the MTLD algorithm for target tracking and position estimation (Task 6). We have also optimized holographic antenna fabrication for effective MTLD system integration (Tasks 3 and 7 and Milestone 3). For the optimal system integration and a quick demonstration of the real-time multitargets laser designation with different codes, we have further investigated other more mature scanner technologies, and selected a COTS high-speed and high-precision miniature x-y galvo scanner for optimization of multitarget designation algorithm and integration into a MTLD prototype (Tasks 6 and 7). We have been fabricating and testing the preliminary MTLD prototype to demonstrate multitarget designation with coded laser pulses (Tasks 7 and 8). We have continued to explore the commercial potential of MTLD (Task 9).

2.0 PROJECT STATUS

The project is proceeding according to the schedule presented in Figure 2-1.



Milestone 1: Completion of MTLD design optimization and performance analysis (6th month).
Milestone 2: Completion of major component development (8th month).
Milestone 3: Completion of MTLD prototype system integration (18th month).
Milestone 4: Completion of prototype system laboratory testing and performance evaluation (20th month).
Milestone 5: Completion of prototype system optimization and packaging (optional) (24th month).
Milestone 6: Completion of system evaluation of Navy field site (optional) (28th month).

Figure 2-1
Performance schedule.

This reporting period we made progress on the following tasks:

Task 6. Optimized the algorithm for target tracking and position estimation.
Task 7. Completing the integration of the MTLD components with COTS elements to fabricate prototype.
Task 8. Began testing the MTLD prototype.
Task 9. Continued exploring MTLD commercial potential.

3.0 PROGRESS THIS QUARTER

3.1 Optimization of Nonimaging Holographic Antenna for Target Tracking and Position Estimation (Task 6)

In the previous reports, we reported fabricating the holographic antenna component using dichromated gelatin (DCG), which is more suitable for multiplexing holograms in a single recording film. However, experiments have shown that to produce large-size, high-quality DCG holograms we need a suitable wet processing facility. The current facility at POC can process good-quality holograms up to 4 in. × 4 in. For the required MTLD size of >10 in. × 10 in., however, the fabrication facility needs to be upgraded, which is currently an ongoing development. To overcome this delay, we decided to use silver halide material for recording a master hologram and then duplicate multiple holograms on DuPont polymer material with a controlled efficiency of each individual fan-out hologram for multiplexing. The current facility will be able to handle the processing of both the silver halide and DuPont materials.

A recording setup for 11.5 in. × 11.5 in. transmission holograms has been build in the laboratory. The schematic of this recording setup is illustrated in Figure 3-1, and a photograph of the lab setup is shown in Figure 3-2. A laser beam at 532 nm (Coherent Verdi) was collimated by a large off-axis parabolic mirror (24 in. × 24 in.). The collimated beam was split by two mirrors with an angle between them, and then interfered on the holographic recording material at the plate holder. A single hologram has been recorded in DuPont polymer, which have tested and shown to have ~90% diffractive efficiency. For MTLD application, the holographic antenna will focus the incoming laser beam onto a series of single detectors. By changing the angle of the incident beam of the playback laser beam, the diffracted beam is moved across the detector position, which was measured as shown in Figure 3-3(a). The measured curve matches the theoretical simulation (Figure 3-3(b)) reported in previous reports. This detuning effect for efficiency is used for target tracking.

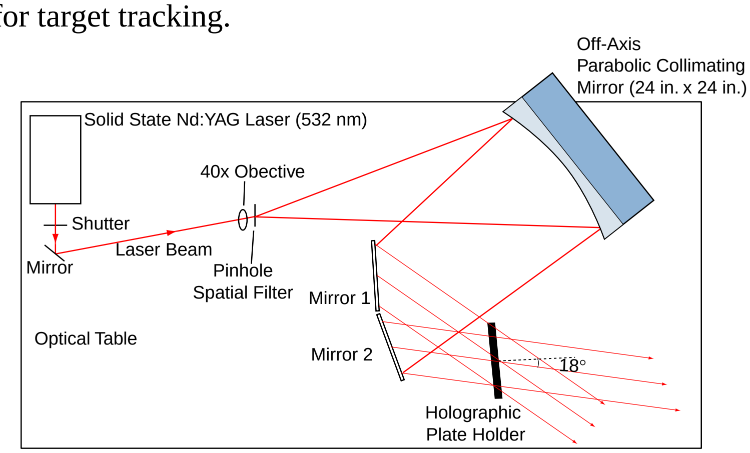


Figure 3-1
Schematic of optimized holographic recording setup for angular multiplexing of holographic antenna. Silver halide hologram masters were first recorded for each design's incident angle. They are then used to produce contact copies of these holograms in the final high-efficiency DuPont photopolymer HOE antenna.

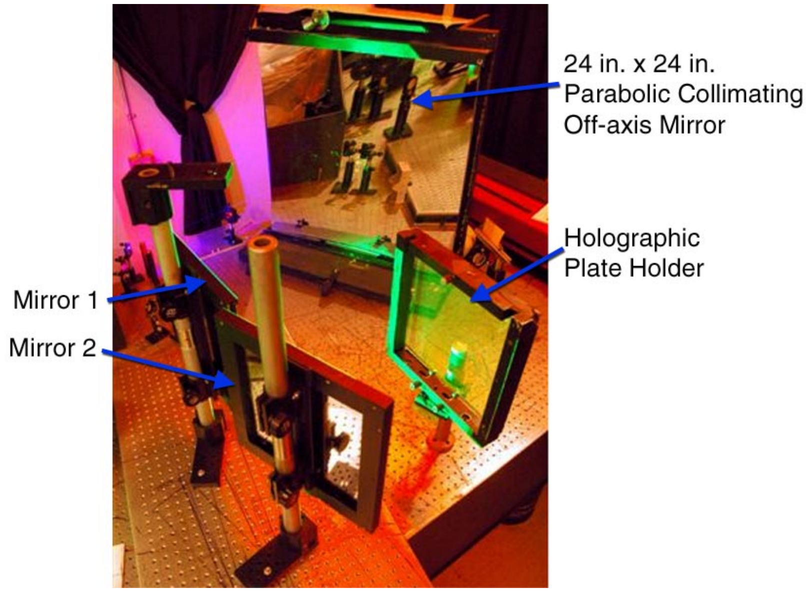
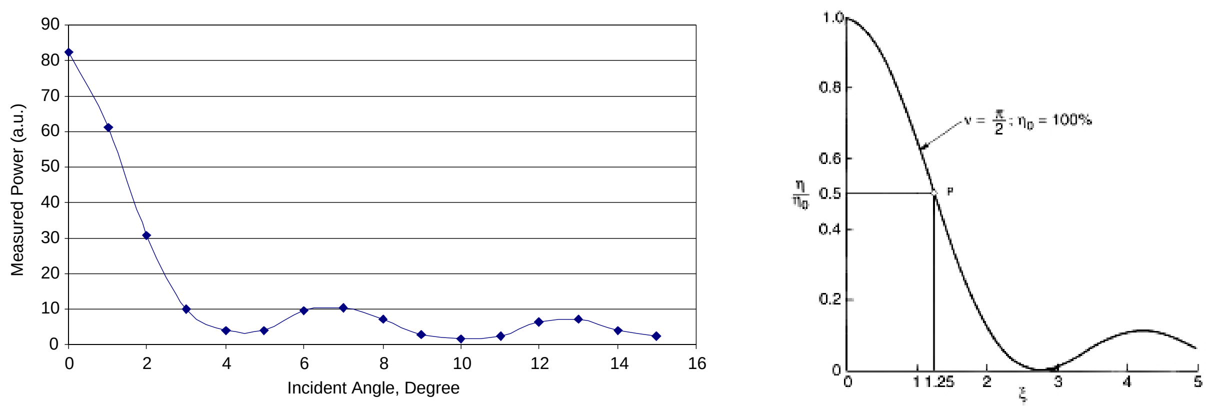


Figure 3-2
Optimized holographic recording setup for angular multiplexed recording of holographic antenna: a laser beam at 532 nm was collimated by the large off-axis parabolic mirror; the collimated beam was split by two mirrors with an adjustable angle between them, which interfered on the holographic recording material at the plate holder.



(a) (b)

Figure 3-3
The angular response of a hologram fabricated by the setup in Figure 3-2, which shows the required Bragg detuning effect: (a) measured result; and (b) theoretical simulation. This indicates that the diffraction efficiency drops or is detuned when the received beam deviates from the Bragg angle recorded in the hologram. When used as an antenna, the efficiency change of the hologram indicates the target angular movement with the respect to the hologram Bragg angle.

Based on the relationships between distances and image angles (*i*), reconstruction (*c*), object (*o*), and reference (*r*) waves as shown in Eqs. (3-1) and (3-2) where $\mu = \lambda c/\lambda o$ and λo and λc represent the recording and reconstruction wavelengths; the holograms recorded at 532 nm can be reconstructed (played back) at 1064 nm, aberration free, as analyzed in previous reports.

$$\frac{1}{R_i} + \frac{1}{R_c} = \pm\,\mu \left(\frac{1}{R_0} - \frac{1}{R_r} \right) \tag{3-1}$$

and

$$\sin\alpha_i - \sin\alpha_c = \pm\,\mu \left(\sin\alpha_0 - \sin\alpha_r \right) \ . \tag{3-2}$$

3.2 Optimization of MTLD Algorithm for Multitarget Designation (Task 6)

In the last report, we investigated three algorithms for multitarget designation, and determined that a single Q-switched laser coded with different PRF codes with time division multiplexing was most cost-effective. We determined that a precision high-speed scanner is required to make the time multiplexing realistic. The angular accuracy of the scanner required to achieve the required time multiplexing for multitargets (5 targets) was investigated. To study the practical aspects of the algorithm, a COTS scanner was selected to design a multitarget designator system. For this initial stage, the holographic antenna part is not included. This will be done in the next stage of prototype integration.

We assumed that the scanner keeps the center of a laser beam within the size of the target. For a 7 ft. (2 m) boat located 5 km away, the angular accuracy required is 1/5000 rad or 0.2 mrad. Typical repeatability of the best galvo scanners is in the microradian range, which is more than enough to direct, lock-up, and track small boats. Therefore, a galvo scanner is used in the MTLD prototype. Table 3-1 shows typical specifications of galvo scanners.

Table 3-1. Specifications of Galvo Scanners [1] Such as That Used in the MTLD Prototype

Moving Magnet Scanner Specifications		6200	6210	6220	6230	6240
mechanical and electrical						
Optical Apertures Supported, Two axis	mm	3	3	5	10	15
mechanical						
Rated Angular Excursions (min)	degrees	40	40	40	40	40
Rotor Inertia (±10%)	$g.cm^2$	0.012	0.020	0.14	1.0	2.4
Torque Constant (±10%)	Dyne-cm/A	1.08×10^4	2.5×10^4	5.7×10^4	1.14×10^5	1.63×10^5
Coil Temperature (max)	°C	110	110	110	110	110
Thermal Conductivity, Coil to Case (max)	°C /W	7.5	4	2	1	0.8
electrical drive armature						
Coil Resistance (at 25°C±10%)	Ω	2.4	4.1	3.4	1.4	1.1
Coil Induction (±10%)	µH	96	98	160	200	255
Back EMF Voltage (±10%)	mV/degree/s	18.9	43.6	0.10	0.20	0.285
RMS Current (max)	A	1.6	1.6	2.6	5.4	7.0
Peak Current (max)	A	6	6	12	25	25
Small Angle Step Response	ms	0.1	0.1	0.25	0.3	0.45
electrical position detector						
Linearity (max over ±10° / typ over ±20°)	%	99.9/99.5	99.9/99.5	99.9/99.5	99.9/99.5	99.9/99.5
Scale Drift (max)	PPM/ °C	50	50	50	50	50
Zero Drift (max)	µrads/ °C	15	15	15	15	15
Repeatability (typ)	µrads	8.0	8.0	8.0	8.0	8.0
Output Signal, Common Mode (±10%)	µA	155	155	155	155	155
Output Signal, Differential Mode (±10%)	µA/degree	12	12	11.7	11.7	11.7

3.3 Integration of MTLD Prototype (Task 7)

We have selected COTS components with optimized performance for the initial stage of MTLD prototype integration. A single laser with a single x-y galvo scanner with a time division multiplexing algorithm, was used for multiple target designations in the prototype. A software program in Microsoft Visual Basic (VB) was developed to control the scanning of multiple beams modulated at various assigned frequencies for multitarget designation. Figure 3-4 shows the block diagram of the MTLD demonstration. Figure 3-5 shows the mechanical drawing of the

scanner. The technical data on this specific scanner is listed in Table 3-2 [2]. A holographic antenna will be integrated into the receiver for testing.

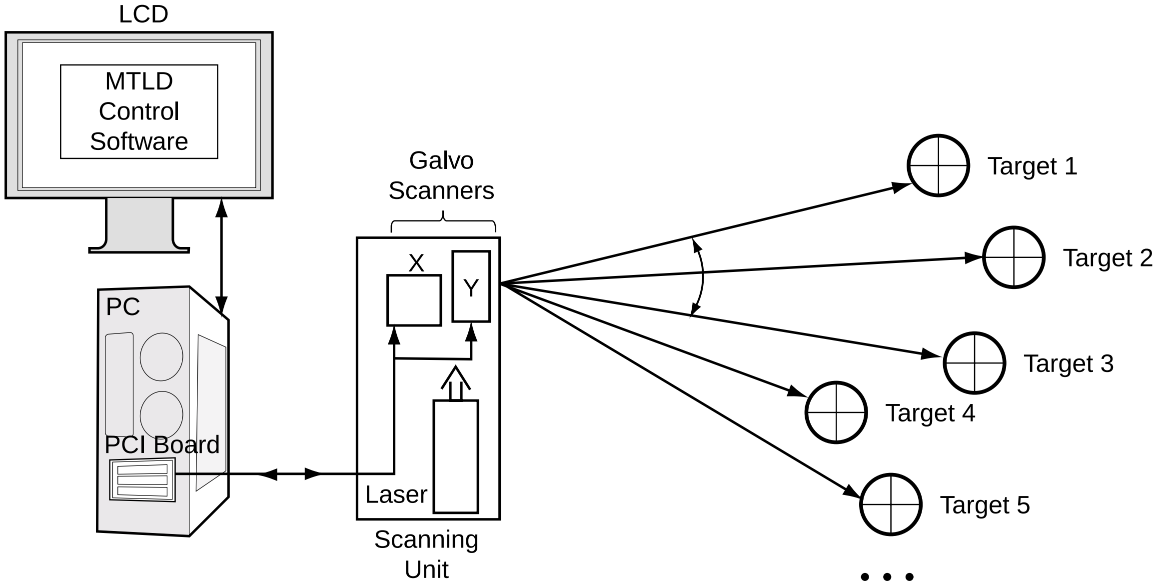


Figure 3-4
Schematic diagram of the intitial MTLD multitarget designation demonstration setup using a single laser and a single x-y galvo scanner for designating 5 targets with assigned individual frequencies with time division mulitplexing (TDM).

Table 3-2. Specifications of CatWeazle Scanner

Power source	115/230 V AV/50-60 Hz
Power consumption	Approx. 30 W
Signal input	±5 V analog, symmetrical or unsymmetrical, ILDA standard
Operating temperature	5°C to 35°C; at higher temperatures use fan blower
Fusing main	Slow 0.2 A
Fusing DC	Slow 1 A

Mechanical Data

Beam height for X-mirror	50 mm
Dimension driver	220 × 80 × 45 mm

Galvo Data

Principal function	Static coil feedback system
Max. optical deflection	50° optical, safe operation at 40° optical
Rise time	<700 µs @ 40° optical <300 µs @ 7° optical
Speed rating	30,000 pps ILDA standard at 7-8° optical angle
Max. current consumption	2.5 A
Dimension mirrors	5 mm × 9 mm
Max. laser power	500 mW
Clear aperture for laser beam	Max. 4 mm

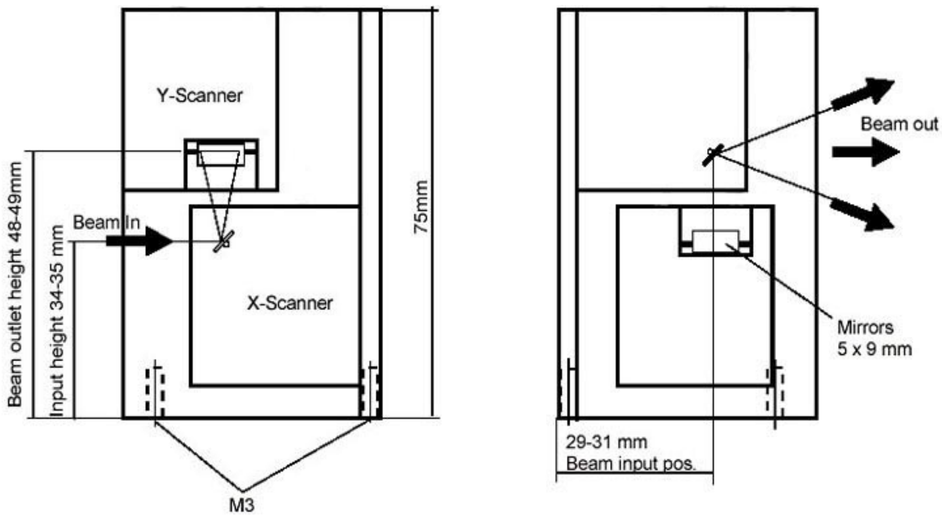
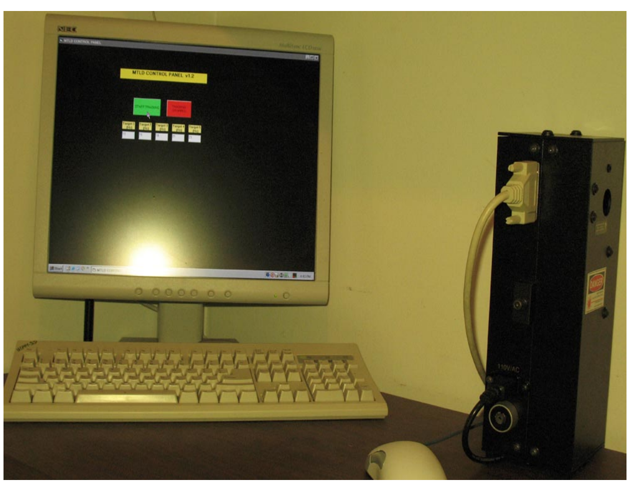


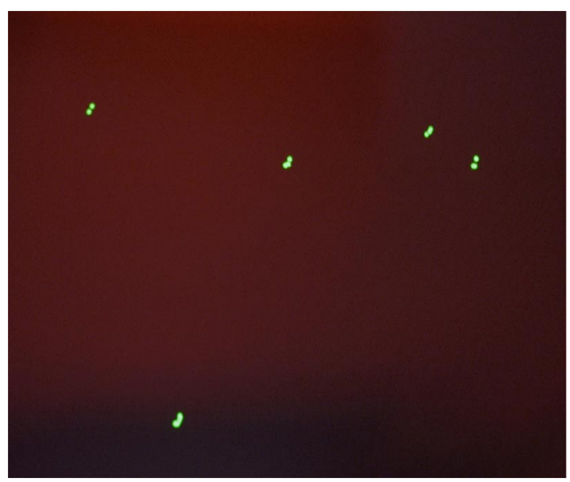
Figure 3-5
Layout of the Catweazle LC II scanner from MediaLas which was used for the initial MTLD multitarget designation demonstration [2].

3.4 Testing of MTLD Prototype (Task 8)

The integrated MTLD prototype has been initially tested and has successfully demonstrated that five laser spots (virtual targets) can be generated in real-time (scanning at 1.25 kHz) with each laser beam assigned to a specific modulation frequency using just a single laser and a single x-y scanner. Figure 3-6(a) shows a photograph of the MTLD prototype demonstration system and (b) shows the 5 laser spots. Figure 3-7 shows one of the beams detected by a photoreceiver with modulation frequency at 20.5 Hz.



(a)



(b)

Figure 3-6
The preliminary demonstration of MTLD for multitarget (five) laser designation.
(a) Photograph of the demonstration system, and (b) Photograph of the five laser spots. Each laser beam is modulated at a fixed frequency (code) and time multiplexed to provide real-time designation of all five targets.

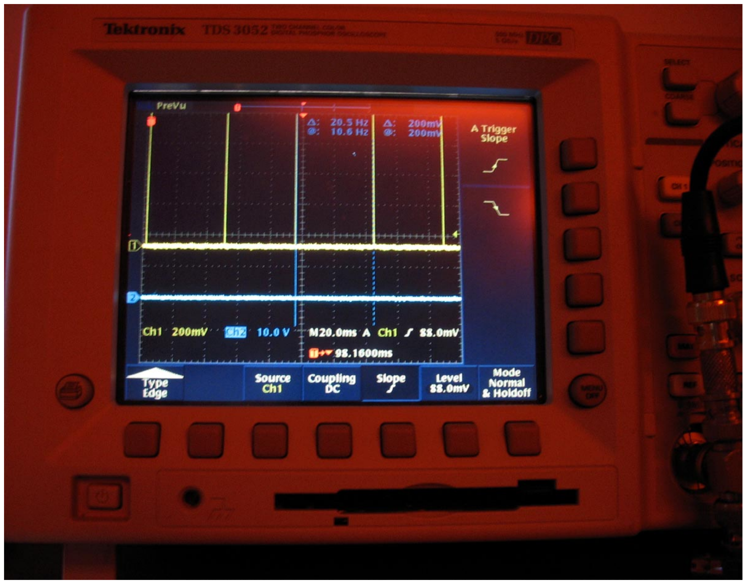


Figure 3-7
Detected signal at 20.5 Hz assigned to one of the beams, which shows the system is working as expected. The 5 beams were modulated at 13 Hz, 15 Hz, 18 Hz, 20.5 Hz, and 23 Hz, with time multiplexing of laser pulse and scan angles.

3.5 Commercialization of MTLD Prototype (Task 9)

Raytheon, EFW, Inc., and QPC Lasers, Inc. have expressed great interest in the MTLD technology, and we are discussing collaboration opportunities to commercialize this technology. During the course of the project, we have investigated and identified several market segments in which MTLD-based devices can be directly applied with little modification. We have had meetings with Raytheon and EFW to explore opportunities in laser designator applications. We have also discussed with QPC Lasers possible collaboration for marketing high-power lasers.

4.0 SUMMARY

We optimized the hologram antenna fabrication and fabricated Bragg holograms. Test results have shown that the Bragg holographic detuning effect agrees with the theoretical simulation very well. We have further investigated the algorithms for multitarget tracking and designation, and determined the most cost-effective and accurate algorithm. The prototype has been integrated and tested. Initial test results have successfully shown designating five targets with assigned frequencies in a time multiplexing manner.

5.0 PLANS FOR THE NEXT REPORTING PERIOD

In the next reporting period, we will produce the final optimized holographic antenna using multihologram multiplexing. This process will ensure good-quality holograms with uniform efficiency, because it is a simple and faster way to multiplex several holograms. We will continue development and testing of the MTLD prototype.

6.0 REFERENCES

1. Datsheet of 6200 Series Galvanometer, Cambridge Technology, 2004.
2. Datasheet of a CatWeazle LC II, MediaLas, 2005.